USING WEB-BASED AUTHORING TOOLS TO OVERCOME THE THIRD BARRIER TO CLASSROOM TECHNOLOGICAL INTEGRATION: DESIGN THINKING

BY

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THESIS

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ABSTRACT

To meet the demand for technologically integrated classrooms, it takes more than simply solving for access to technology and convincing teachers of their use. The literature presents design thinking as an additional barrier to this goal. Although the emphasis has gone towards training instructors to attain technological knowledge, there are several limitations to such an approach. In this study, a process of co-design was evaluated as a strategy to develop design thinking on integrating new web technologies into the classroom. By recognizing separate knowledge domains, collaboration, and iterative cycles, the process was identified as the Instructor-Developer Design Process (IDDP).

Instructors participated in working with developers to extend the design of features for a web-based authoring environment that uses WebXR technology to provide cross-platform accessibility, run-time network syncing, custom asset imports, and user interactions. With an explanatory case study that involved interviewing two instructors that implemented lessons using the platform, the purpose was to investigate how those characteristics that make up design thinking were shaped by the process. Even though there are limitations due to having a small sample size, this study supported our research hypothesis that going through the IDDP led to more design thinking on the integration of web tech into the classroom. It also recognized the potential obstacles in this process such as the translation of ideas to developers and emphasized collaborative prototype testing as an essential activity for the process.

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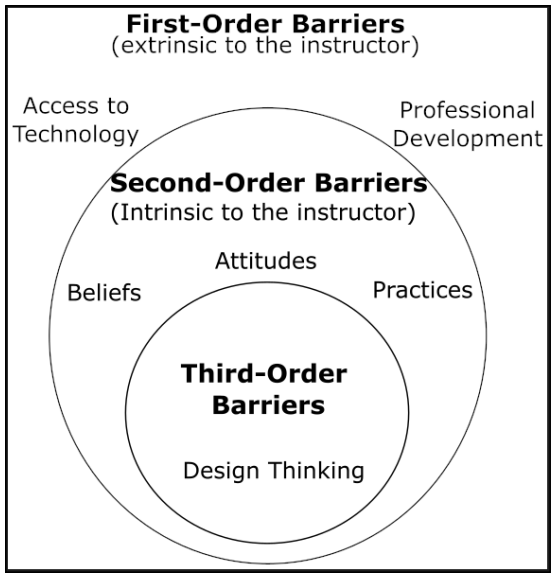
INTRODUCTION:

TOWARDS TECHNOLOGICAL INTEGRATED CLASSROOMS

As the pandemic has accelerated a shift of the classroom into online spaces, there has been a sense of urgency to the question of how to assist teachers in integrating technology within their teaching (Teräs et al., 2020). This concern was especially evident before as a transformation from the industrial age to the informational age meant a priority towards innovating educational practices (Reigeluth & Joseph, 2002). Nevertheless, this attempt to reach technology integration within teaching exposes different levels of barriers for success (see Figure 1). Within the first level, there is the issue of access to technology and training. The second level brings teachers' beliefs of technology into perspective, while the third level brings us to consider barriers to "design thinking," which refers to the capacity to problem solve using technology within teaching (Tsai & Chai, 2012). These levels bring us to consider that it is not enough for teachers to have access to technology and to have a desire to implement it. This is because they still face the challenge of being able to design think technologically integrated lesson ideas for a dynamically changing classroom environment.

Figure 1

Barriers to technological integration based on the ideas of Tsai and Chai (2012)



In overcoming this third barrier, training and professional development have been used to assist instructors in knowing how to integrate technology by knowing how it fits within their pedagogical and content knowledge (Koehler et al., 2007). This has faced challenges as teachers might experience hesitation towards problem-solving technological issues compared to dealing with issues related to pedagogy and content (Archambault & Crippen, 2009). Training that provides instructor modeling, hands-on practice, and multiple design cycles does show promise to help develop acceptance and confidence in using technology (Brush et al., 2003; Koh & Divaharan, 2011). However, this comes in the face of constraints to the teacher's time, capacities, and the learning curve required to learn new technologies (Hew & Brush, 2007; Pajo & Wallace, 2001). Facing these limitations and recognizing the merits of current approaches, it looks prudent to investigate design processes that not only accommodate but promote further design thinking for integrating technology into the classroom.

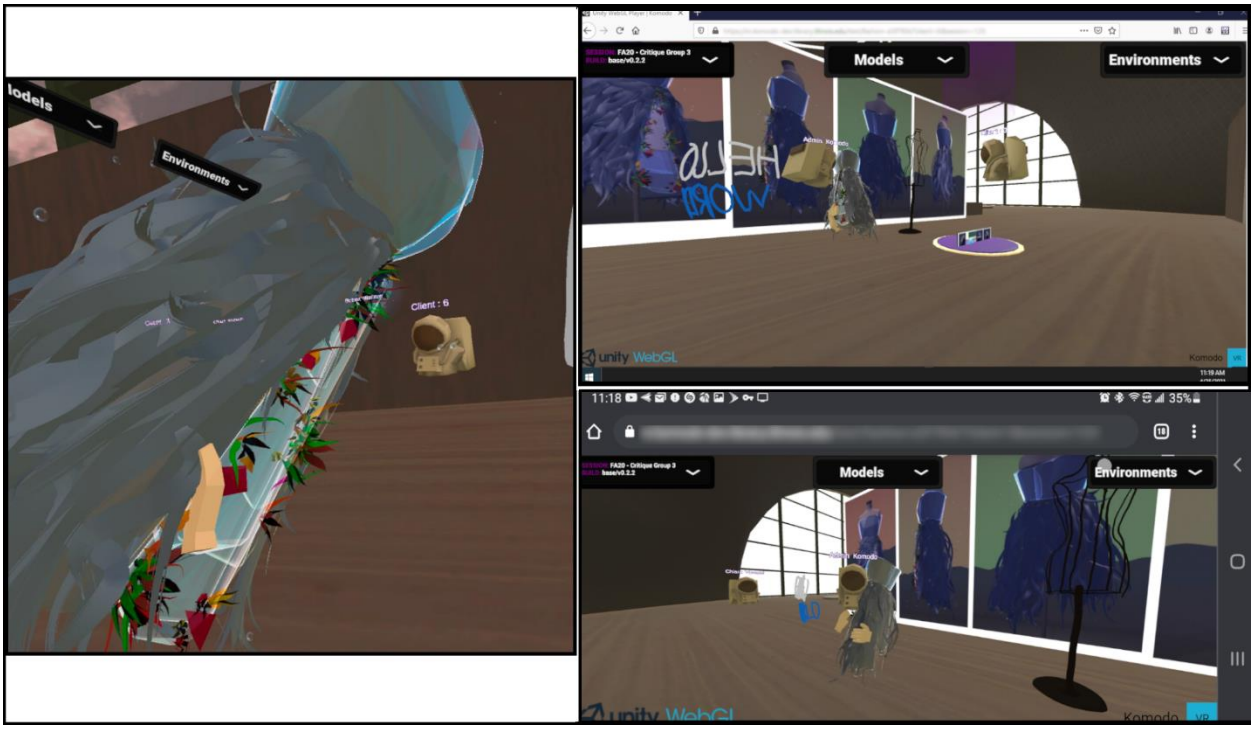
One promising design process involves having developers collaborate with instructors to materialize the specific features needed for integration to happen. This can be considered a co-design strategy that involves the instructor not only making suggestions about an application but having them be decision-makers as well (Burkett, 2012). This was the approach taken for designing and developing instructor-relevant features for a web-based authoring platform that supported their ideas on integrating virtual reality into the classroom.

An Authoring Environment for Instruction

Komodo was developed with the Unity game engine using a WebXR plugin to develop virtual reality applications that can be accessed through a website. The web context allowed us to target desktop and mobile devices as well by providing controls to navigate the 3D scene through keyboard and touch input. Adding runtime networking within the prototype, the platform was able to have a synchronized 3D environment that people can participate in using different devices. Further development brought about the ability to import custom assets and expanded the features available to the user by including teleporting, annotating, asset grabbing and the chance to change their situated environment. Figure 2 demonstrates these efforts by taking a screenshot of the platform using the Oculus Quest (left), an HP pavilion laptop (top right), and a Samsung Galaxy Note 10 phone (bottom right). This context of features served as a baseline to bring instructors to discuss further customization of the platform to fit their integration goals.

Figure 2

Komodo: A web-based platform for authoring instructional spaces.



Note. Additional Information can be found at https://komodo-dev.library.illinois.edu/about

Making Sense of this Instructor-Developer Collaboration

These efforts began by discovering teachers that had a desire to integrate web-based social virtual reality within their lessons and commit to iterative cycles of feature design with developers. This brought opportunities to obtain a shared understanding about what was needed for integration to take place. The availability of a prototype to review together gave a basis for assessing those needs. Feedback assisted developers in knowing what needed to be changed, removed, or added for formulizing the next prototype to test. For instructors, testing helped them gain comfort with the platform-tools and gave them a point of reference to think about integration, which led to class implementation. Insights from implementation were then brought back into the collaborative domains informing design thinking and future prototype iterations for

future implementations. To illustrate this process and help the reader understand the structure of working with instructors towards implementation, Figure 3 was created for this study to make sense of the relationships involved between different phases and roles.

Figure 3

The Instructor-Developer Design Process

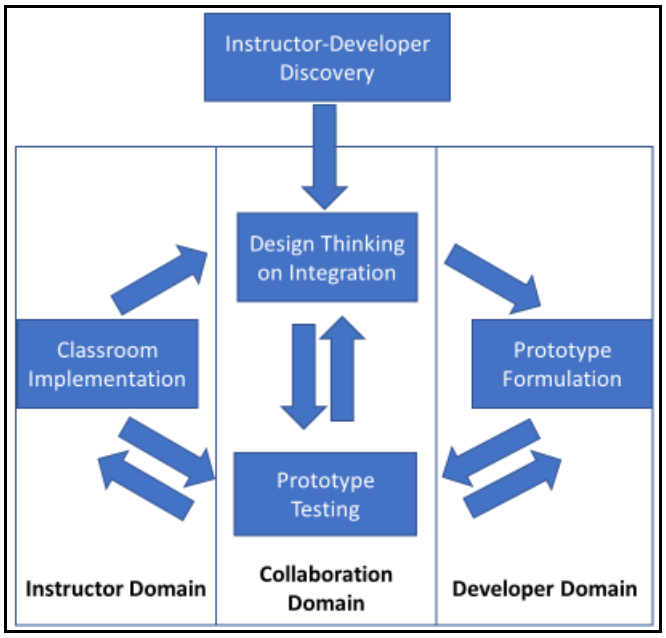


Figure 3 illustrates the process starting when the instructor and developer discovered each other to achieve class integration (top). This resulted in collaborating on design thinking to figure out how to integrate it into the classroom by identifying features needed through prototype testing together (center). During this collaboration time, feedback is provided for developers (right) to formulate an improved iteration. This process eventually led to instructors implementing (left) the platform in their classroom, which informs either more design thinking on integration or further testing.

Labeling it as the *Instructor-Developer Design Process* (IDDP) helps describe it as a collaboration of different domains that involves a front to achieve design goals. Making this

process identifiable by its central themes of having separate knowledge domains, a collaboration dynamic and iteration cycles of implementation helps set a way to analyze how IDDP can characterize design thinking on integration. To evaluate this theory, an explanatory case study of two instructors who participated in the design of the Komodo features took place. This consisted of doing post hoc interviews with instructors in Material Science and Fashion Illustration at the University of Illinois Urbana-Champaign who went through a collaborative iterative process to implement web-based virtual reality lessons. Their classroom sessions using Komodo ran in Fall, 2020 and are currently running again for the Spring, 2021 school year.

Through analyzing feedback provided on their previous and current instructor experience, reflections, and future projections, the goal is to paint a picture of how elements of this design partnership shaped instructor design thinking. Making sense of this data involved us capturing common themes in the literature regarding what design thinking is to explain and describe how it might be shaped by the underlying process. Therefore, finding connections between elements that make up the IDDP and how they shape characteristics of *Design Thinking on Class Integration* (DTCI) can help answer the central research question in this paper:

- Does going through the Instructor-Developer Design Process lead to further design thinking on classroom integration from the instructors?

REVIEW OF LITERATURE

The review involved searching for published text between 1980 to 2021 in databases including Google Scholar. A focus was placed on obtaining an informed perspective of how the IDDP can impact DTCI. To achieve this, exploring the essential elements of the process, which involves access to prototypes and the collaboration between instructor-designer became important. An equally crucial objective was knowing how to evaluate design thinking by identifying general themes that can help us recognize and assess it within the interviews. This was done to have a basis to evaluate the research question and know-how this study fits within the literature and how it can contribute to it.

Technology Integration Through Prototypes

Considering design thinking as the third barrier to technology integration came from recognizing that for integration to take place it is not enough to remove first and second-order barriers (Tsai & Chai, 2012). The dynamic nature of classroom context and students brings a need to adapt and reorganize learning content. This brings us to see the state of integration not only in terms of technology but a state of the art in teaching. With this perspective, the importance of engaging in instructional design using technology becomes apparent to obtain proficiency in practice.

Design fields typically engage in such practice by externalizing design thinking through artifacts such as prototypes (Cross, 2004; Lawson, 1997). Through these artifacts, they can develop their design thinking by reflecting on their design decisions. The same can be said with tools that enable instructors to create and refine their lesson conceptions, which can help them reflect on their decisions and processes (Cameron, 2006). These benefits extend to affecting second-order issues such as computer feature comfort by helping teachers "understand and

engage with the pedagogical affordances of computing devices in their classrooms" (Makki et al., 2018). Although design tools can potentially scaffold design thinking by expanding the scope of lesson ideas, evaluating the effectiveness of these tools in relation to design thinking and education has not received much attention in the literature (Koh et al., 2015).

Evaluating Design Thinking for Classroom Integration

According to Design Thinking for Education (Koh et al., 2015), defining design thinking to measure it may be complicated by the "contextualized nature of design" (p. 118). The complexity becomes apparent when recognizing that the development of such thinking involves us to consider perceptions that teachers may have about their design practices, analyze the design process itself and the outcomes of that design. Therefore, it looks ideal to evaluate perceptions, processes, and outcomes related to a design experience to obtain a better picture of how IDDP served to characterize them.

- *Design Perceptions* determine confidence in design practices, how design problems are interpreted, and what design processes are used (Koh et al., 2015).
- *Design Processes* provides us with insight into the strategies used during the design phase. Although defining design processes and identifying effective ones has not been straightforward to represent, “empathy building, collaboration, and iterative prototyping” have been identified as typical components of programs and training that try to address design thinking (Koehler et al., 2007; Koh et al., 2014; Starr et al., 2020). Another characteristic found in the literature supports design thinking having an “absence of well-ordered and well-defined design stages” (Summerville & Reid-Griffin, 2008). This informs us that the process involves a back and forward shifting of ideas through social exchanges until they reach a state of consensus by a team.

- *Design Outcomes* can help us understand design efforts by reflecting on what instructors sought and felt they were able to achieve. This is important because teacher's experience with technology and successful implementation of it determine continued usage of the technology (Hughes, 2005).

Collaborating on Design Thinking

Online teaching has seen technology as a requirement but pedagogy as critical to its success (Palloff et al., 2001). To meet expertise within instructional and developer domains, collaborative teamwork has been seen as important and has been used in online course development (Meyen et al., 1999; Moore & Kearsley, 1996). This is especially crucial considering that design thinking within the educational context has been recognized as emerging from a social process of ideation and refinement and involving iterative cycles of "reflection-in-action" (Schön, 1983). This comes from teacher's existing classroom knowledge that helps them evaluate design ideas after each lesson designed cycle. Studies have explored this collaborative workflow of instructors working with at least one technologist highlighting the benefits of having clear roles and issues in taking such an approach.

One study, in particular recognized "subject matter, design knowledge, resources, and technical skills" as critical to the process of designing an online course (Kang, 2001). Others have mentioned challenges in acclimating faculty members to a new practice since it is a "negotiated role," and state the importance of the designer having expertise in interpersonal, technical, and instructional domains (Carnevale, 2000; Fredericksen et al., 2000; Luck, 2001). Within working with different knowledge domains, White (2000) identified barriers to communication that could happen. By setting explicit responsibilities, expectations, and having mutual values and respect for their knowledge domains, Meyen et al., (1999) showed a potential

to face such issues with misunderstanding. Strategies have also been brought up to engage instructors in co-designing tools for their instruction by identifying discussion of physical artifacts and scenarios, customizing prototypes, and the creation of user stories (Matuk et al., 2016).

The outcomes provided a glimpse of the collaborative process being a "valuable learning experience and an active model of faculty development" (White, 2000). This participatory method towards co-design that aligns with the teacher's goal and expectations has been recommended for reaching design and user needs within web-based learning environments (Matuk et al., 2016). Further assessment of how these collaborations can impact instructional practices has emphasized the need to focus more on the role of teaching instead of just technology. According to Xu and Morris (2007), this can be done by familiarizing instructors with the platform, helping them develop pedagogical content, and showing them how to integrate interactivity within the course structure.

Points of Consideration for the Study

The review provided an appreciation of the role that prototyping, and a collaborative approach can have and brought us to see the importance of setting explicit responsibilities between instructional and technical experts. IDDP meets these considerations by splitting responsibilities as a framework and having both collaborate mainly for design thinking on integration and prototype testing. There have been challenges in the representation and interpretation of design processes as mentioned by Koh et al. (2015). To try to meet these concerns, the model attempts to offer some simplicity by relying on a few crucial aspects to describe the process and offering a general direction on roles and collaboration. Another possible criticism of IDDP relates to it being a model. Cognitive psychology and research traditions in

behavioral sciences see design phases teaching us little about design thinking compared to looking at small segments of the process through protocol analysis (Goldschmidt, 2014). However, the purpose of the model is to help make sense of the complexity involved within a defined instructor and developer partnership to express key processes that serve to characterize DTCI.

Defining design thinking within this framework exposed research areas in need of consideration. These include establishing validated measures, investigating prototyping as a teaching scaffold of design thinking, and research on how the integration collaboration can impact teaching. In trying to measure design thinking, we are reminded of the complexity that it brings. Nevertheless, prior research helps us conceptualize and consider design development through design perceptions, processes, and outcomes. Themes within those scopes of experiences seem fitting to investigate the characterization of DTCI and expand on the presented gaps in the literature.

METHODS

Mode of Inquiry

To explain how IDDP characterized design thinking on integration, an explanatory case study was used. According to Yin (2014), case studies are an "empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially in boundaries between phenomenon and context that may not be clearly evident" (p. 18). In this study, the goal was on investigating the instructor's DTCI by considering the characteristics that were identified in the literature. Taking an explanatory approach also helped us to answer "how" IDDP was able to further DTCI since it could help explain potential complex causal links as well as describe the intervention and the real-life context where it occurred (Yin, 2014).

Participants

Participants are 2 instructors from the University of Illinois Urbana-Champaign who were able to go through the IDDP using the Komodo authoring tool to implement at least one classroom session for their Fall, 2020 course. One participant was a Clinical Assistant Professor in the School of Art + Design who taught a course on Fashion Illustration. The desire for integration came from seeking a virtual space where students can critique garments created through another virtual reality application called Tiltbrush created by Google. The second participant was an Associate Professor in the Department of Material Science and Engineering teaching a course on Computational Material Science and Engineering Microscale. The intention for integration was founded on an attempt to teach material science concepts such as Miller indices in a way that is more interactive and concretely through virtual reality. To accomplish this, both instructors worked with developers through the IDDP process to help formulate the tools needed to achieve integration.

Materials

An interview guide (see Appendix B) was used for this study to help direct participants to discuss their design perceptions, design process, and design outcomes regarding their past Fall session using Komodo and their upcoming attempts of using it again for their classroom lessons. Questions on design perceptions and design process are furthered divided to account for concepts that the literature review identified as being relevant.

Background of Komodo and IDDP

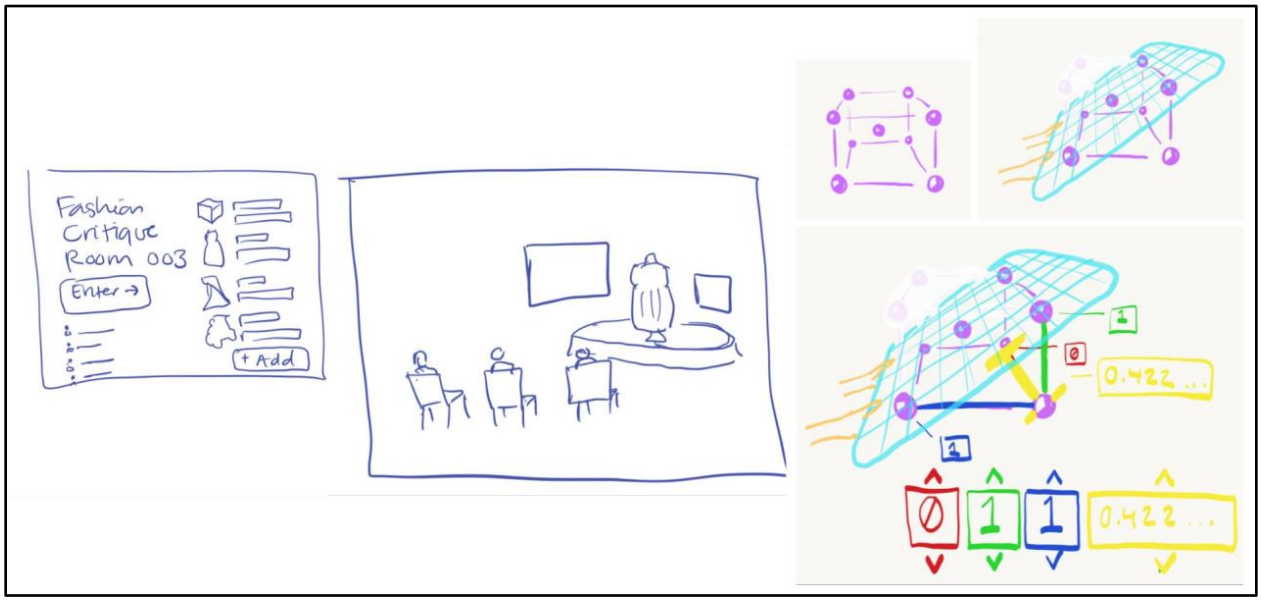
Komodo was initially funded by a seed grant from Technical Services and coordinated by VR@Illinois at the University of Illinois Urbana-Champaign. The core platform is currently being funded by Grainger Library while extensions to the core are being funded by research grants. The discovery of the partnership for participants in this study took place in January of 2020 after instructors inquired about a grant to assist them with virtual reality integration. Some of these instructors were referred to a team of three developers working on the authoring tool. The main developer team consisted of a faculty working as an Information Technology Technical Associate, a Project Manager, and the author of this study. The project manager served as the primary contact for instructors by meeting with them every two weeks to once a month. Initial meetings focused on exploring instructor desires to use virtual reality and obtain a shared understanding of how integration in the classroom would look like. This consisted of doing brief low fidelity prototypes through drawings to explore design considerations together.

Figure 4 shows the sketches that were used to obtain an understanding by the developer of the features envisioned. The left sketch came out of conversations with the Fashion Illustration instructor to confirm design ideas with the use of low fidelity prototypes. On the right, there is a more involved sketch that was used by the developer to validate understanding of

a feature that enables the visualization of planes cutting through atoms. It also served to confirm understanding of a material science concept called Miller indices with the instructor.

Figure 4

Developer Sketches Used to Understand Instructor Ideas for VR Class Implementation



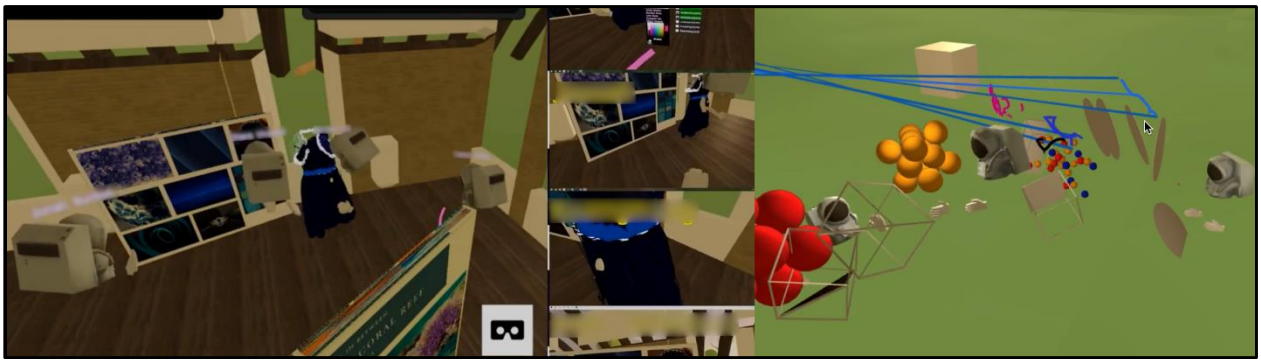
The conceptualization provided a context for generating a story map to present to the rest of the developers for formulating a high-fidelity prototype using Unity with WebXR specifications. The development involved working on top of a base implementation of the web platform that included features such as model import, environment switching, network syncing, and the user being able to grab and scale models. This provided a foundation to build instructor customization within the experience and to provide a prototype to test. Collaborative testing with the instructor assisted in identifying bugs in the code and validating if the features were a good representation of their design visions. This eventually resulted in class implementation by the instructor leading the session while the developer(s) were present for technical support.

In Figure 5, we can see how the implementation looked like. On the left is a snapshot of one of the first implementations with the Fashion Illustration class. The instructor and students

are situated in what is called a Critique Room using Komodo where they are providing feedback to each other over garments created through a different virtual reality application called Tiltbrush. In the middle, we can see the perspectives of different students. On the right, the Material Science instructor ran his Fall session teaching concepts such as indexing crystal planes using Miller indices.

Figure 5

Class Implementation with Komodo



Procedures

A semi-structured interview was conducted to explore the dynamics of the process and how they characterize DTCI for instructors. Developers were not interviewed because the focus was on obtaining a specific understanding on the instructor's side of class integration. This method was used to obtain rich data to build on the literature through elicit meanings, perspectives, and understandings (DiCicco-Bloom & Crabtree, 2006). Interviews consisted of using a guide (see Appendix B) to specifically address design perceptions, design process, and design outcomes to assess the characteristics that IDDP may help foster. One-hour sessions with each instructor were recorded using Zoom teleconferencing software. The recordings were then reviewed for relevant discussion about IDDP and DTCI.

Establishing Themes from Prior Research

Three themes were established based on the central elements that make up IDDP which comprises separate knowledge domains, collaboration, and iterative cycles. The first concept recognizes a separation of responsibilities between developers and instructors placing instructors in charge of class implementation. Meanwhile, collaboration emphasizes the connection between both domains that are brought together through the prototype testing and integration design thinking phases. Iterative cycles represent the continuing nature of this process that happens after a class implementation.

Previous literature on design thinking provided a theoretical framework to know what to look for in the data to find characteristics of DTCI. These are divided amongst perceptions, processes, and outcomes (see Table 1). From the literature review, attributes fundamental to each were identified. This helped us develop a framework to evaluate design thinking by taking a deductive approach by finding relationships between these attributes and the statements made by instructors. Finding these associations helped evaluate how elements of the IDDP shaped DTCI.

Table 1

Design Thinking Characteristics

Design Perceptions	Design Process	Design outcomes
• Confidence in design practices • Design problem interpretation • Design process choices (Koh et al., 2015)	• Empathy building • Collaboration • Iterative prototyping • Absence of well-ordered and well-defined design stages (Koehler et al., 2007; Koh et al., 2014; Starr et al., 2020; Summerville & Reid-Griffin, 2008)	• Reflection on design efforts • Continued usage of technology in the classroom (Hughes, 2005).

RESULTS

To provide an overview of the results of the study, the sections are separated by the themes that comprise IDDP. Instructor interviews from Fashion Illustration (FI) and Material Science (MS) are summarized to relate the conversation to the themes.

Separate knowledge Domains

FI identified that a class goal is to teach students to sketch with a pencil and converting it into a digital drawing. Using software including Photoshop and Illustrator helped her developed confidence to use Tiltbrush to create garments during 2019. Seeing how quickly students became adjusted and engaged, FI felt compelled to continue using it for upcoming semesters. As a result of covid, the VR activity did not take place for a semester. However, having access to Komodo, FI was able to reintroduce the activity for 2 days in Fall 2020 during the pandemic.

MS expressed the struggle in being able to articulate material science concepts and has realized how more interactive mediums can serve to portray concepts in a way that can help students understand. MS described this problem by stating:

> The challenges that we are facing in these courses, the thing that we want to illustrate is how atoms form certain crystal lattices in a material… and there is a mathematical description on how to deal with this what we call a crystal lattice, and explaining that to students is quite challenging because it is a three-dimensional thing.

MS mentioned that he has used software that provided 3D graphics to explain materials before but felt that it lacked engagement and interactivity. Therefore, MS saw interest in Komodo because it offered a platform to be part of a virtual space with students and allows for importing 3D objects into the virtual world to look at together.

Collaboration

FI created sketches to show the environment and tools she envisioned and to assist her in expressing the ideas to the developer. In regard to this, FI stated: “I had some ideas, I just explained what my needs where and talking with (Developer) and having regular meetings every month.” After meeting with the developer to explore ideas, FI states that the Critique Room started to materialize. FI mentioned that she did have many features and tools in mind but the outcome of the virtual environment “looked a little different.” FI reported that despite the environment being different she saw it as a great starting point since she felt that the environment she was thinking about was too much effort to produce. FI mentioned that she was better able to provide feedback whenever she was trying the virtual experience instead of outside because one starts “forgetting things.” In implementing the platform for her class, FI recognized that students needed time to try out the experience to use it, so she provided a few minutes to get oriented to the space and controls.

MS informed that collaboration with the developer consisted of going back and forth sharing screens and emails. MS saw having live meetings with the developer as productive instead of just relying on emails and found it helpful in communicating and explaining concepts especially for someone that is “far from the field.” MS stated that previous experience using a different visualization tool gave indicators of things that students struggled with. This extended to avoid grading for using the platform because if something fails technologically, he does not want students to be responsible. MS mentioned that this experience helped deduct what Komodo needed when testing the prototype with the developer. Before introducing it to his classroom, MS saw it important to know what needed to be learned hands-on and what needed to be taught through a PowerPoint to use Komodo. In speaking about how he became acclimated to the platform, MS felt that it consisted of “50% self-explanatory and 50% help with (developer) by

him demoing it once led to me feeling more comfortable." After MS coordinated to obtain headsets for the class, two students were able to join him within the virtual environment while the rest watched as spectators using their laptops.

Iterative Cycles

Having done two implementations, FI looks to provide instruction material that can help provide "real time" instruction on the controls and features to better introduce students into the experience. In talking about the discussion with the developer after implementation, FI reported that:

> After the critique (event) we also had a meeting with (developer) talking about the experience what worked and what didn't work, so after the critique, we said hey look maybe we need to adjust these few things that didn't work so these features will be adjusted or they are still working on them.

FI stated that she is thinking about upcoming semesters and how she could include more time using virtual reality, especially when in-person classes begin again. Specifically, FI mentioned that during class implementation she noticed a need for a feature that allows students to leave or record comments for other student's work. FI stated that recent class implementation of Tiltbrush gave further insight to limitations such as the type of brushes and not being able to render fabrics. FI feels that these discoveries are informing future implementation iterations and "how this project is approached."

After implementation, MS reported that Komodo had all the features needed for his purpose and attributes it to having done multiple testing iterations with the developer. In regards to a question about him having a desire to add new features, MS reported that:

> For this first iteration, and maybe for the second iteration, to gain experience on how students interact with this and what they are seeing, I think the features that are there, are more or less the features that we need, I think, that happened because me and (developer) met a bunch of times beforehand and then those got implemented, the version that we actually used for the class, I think we had most of what we needed, I might say.

MS did recall a discussion with the developer in implementing a feature that shows atoms moving around but feels that it might be good for a different class that he is teaching. MS felt that covid was the biggest interruption to implementation, which resulted in a small number of students being involved. MS stated that additional iteration with students could refine the experience further over time. MS expressed wanting to revisit and use the platform consistently in the upcoming Spring and Fall semesters through the computer lab once there are more in-person classes. Once he has a larger group of students, MS reports wanting to expand using Komodo to improve how he teaches material concepts that he has identified as difficult in the 2D physical world.

DISCUSSION

Through the two instructor accounts, we can reasonably state that the IDDP process has a role in furthering design thinking on integrating the web tech by exposing the prevalence of the specific characteristics that make up design thinking. Even though instructors had a different reason for integration and a unique approach in engaging within the IDDP, their statements speak on how their participation reinforced further thinking. Assessing these through the themes that make up the IDDP helped evaluate what was essential, missing, and could receive more attention. To synthesize the evidence across both cases, an analysis of their design perceptions, process and outcomes is provided.

Design Perceptions

FI's confidence came from her experience using virtual reality in previous classrooms and her goal to bring illustration to digital software. This confidence helped her communicate ideas to the developer by interpreting design needs through sketches. Despite seeing the result of the developed Critique Room being "a little different," FI still felt that it was a great starting point to use for implementing in her courses. From these instances, we can extrapolate changes within FI's design process choices by relying on sketching to supplement transmitting her ideas to the developer. Finding out that those ideas may not translate clearly, FI showed a shift in her design problem interpretation by adjusting her design goals to what was currently available within the prototype.

Similar to FI, MS showed confidence in design practices from his previous use of software, but his focus has been on using it to help students understand material science concepts. MS was able to display a clear design interpretation based on his past experiences using various applications and mentioned that he was looking for a platform that can provide

more interactivity and 3D visualizations. Introducing Komodo seemed to shape his design process interpretation by recognizing that there are other tools that he can use for teaching including sharing a virtual space with students and being able to annotate. However, using Komodo to accomplish his goals, he found it involving "50% self-explanatory and 50% help with (developer)" to become comfortable. This informs us how confidence in design practice with unfamiliar software can be mediated by the collaboration element of IDDP.

Design Processes

MS and FI approached this design process differently while still exhibited common traits. Even though MS reported experiencing limitations to implementations due to covid, he was able to involve himself in doing iterative prototyping and collaboration with the developer. This involved MS testing on his own and testing with the developer to provide feedback. This showed that in the absence of class implementation, there was still an opportunity for MS to engage in the process. Design process characteristics are highlighted by recognizing that it consisted of an absence of well-ordered and well-defined design stages as well as iterative prototyping and collaboration within the IDDP. MS unique process resulted in him thinking and working with the developer to have the features necessary for implementation and accommodating for issues that students may encounter with the platform, which eventually led him to have all the features he wanted before his class integration session.

FI's design process was more focused on enhancing her classroom goals. Having more access to classroom implementation opportunities, she was able to get insight into how students were approaching the virtual reality space. This allowed her to collaborate and engage in the iterative prototyping process with the developer using feedback from students. In her second iterative prototyping using the Critique Room, FI was able to recognize that students needed time

to learn the controls and become adjusted to the experience, which has been a design consideration she has discussed and tried to figure out with the developer. By reflecting on the process, it is recognized that FI was exhibiting empathy-building by thinking about how to best accommodate students into the experience. This involved collaborating with the developer to know how to approach the problem, which has involved brainstorming and prototyping possible solutions.

Design Outcomes

Outcomes came from seeing their design efforts and their desire to continue using the application. From earlier discussion, we can see that FI saw that there were obstacles to getting her ideas concretely represented, but FI still saw what was there as a "great start." Regarding the two-class implementations, she reflected on the design efforts as well. This included being able to recognize the need for a tutorial to acclimate students more efficiently to the platform. To address this issue, FI stated that she is considering including more instructional time in virtual reality in upcoming semesters especially when in-person classes resume. From this narrative, we can identify reflection happening in seeing the result of design efforts with the developer and in class implementation. Meanwhile, a continued sense to use the platform is sparked by opportunities once in-person instruction begins and obtaining further feedback from the experience.

In MS conversation, he also showed reflection over his efforts and plans for future implementation. MS reflections placed him toward looking forward to class implementation with students to refine the experience. MS specifically expressed that he feels that the platform has everything he needs but testing with students will give him better insight on improving it. MS stated that once in-person classes begin again he is looking forward to using the platform

consistently in the upcoming semester to figure out if something is missiong. MS also shared plans to think about how current features can be applicable to a future course he will be teaching about atoms.

From these accounts, several points mark how being active within the IDDP furthers design thinking on integration. By capturing the characteristics that have been identified in the literature regarding design thinking, we were able to find links between the process and how it shaped them. The review helped identify the importance of communication within this process and how there may be issues in translating ideas. This was the case by FI feeling that the prototype result was different from what she envisioned, and MS case of explaining complex topics. It also emphasized the use of prototypes as a potentially effective tool to scaffold design thinking. This was supported by FI stating that she was able to give more useful feedback when being present with the developer while using the application, and MS statement that it involved "50% self-explanatory and 50% help" by the developer testing it with him to gain comfort. In this regard, we can see some support for design tools such as prototypes being a scaffold for design thinking.

Limitations and Future Directions

One main limitation to this study relates to generalizing the findings. This is due to only having two participants as a representational sample and participants only reflecting instructors teaching university-level courses. Although this is partly the result of the novelty of the initiative, which has only given time for two instructors to have a successful implementation, it does speak of the need for more research in this area especially encompassing bigger sample sizes and a diverse instructor body.

The attempt to obtain rich data from a complex process motivated the use of an explanatory case study with interviews. The issue that arises from relying on post hoc semi-structured interviews to obtain the data are questions on both the reliability and validity of the result (Alshenqeeti, 2014). In this instance, protocol analysis such as linkography that uses a more systematic approach to studying the design process through the idea of "design moves" can offer more fidelity and reliability (Goldschmidt, 2014). However, this comes at the cost of not capturing the complexity of a situation that is captured through case studies (Yin, 2014).

Results from this study bring additional questions about collaborative initiatives using prototypes to promote DTCI. One point for further inquiry relates to the importance that preconceived lesson ideas are for developing DTCI within the process. Also, thinking about the deviations in instructor translation of ideas within formulated prototypes, it would be valuable to know how these incongruencies can impact further DTCI.

CONCLUSION

As global challenges define priorities, we are placed in the situation of how to meet a changing landscape of education. Even though access to technology and a desire to bring it to the classroom are prerequisites of its actual use, previous literature informs us that it is not enough. This brings us to noting a more intricate barrier to reach integration: design thinking. Building such skill has resorted to training in the face of current instructor struggle with time and resources. By bringing the idea of the Instructor-Developer Design Process from a process of co-designing features for the Komodo platform, a different strategy to promote design thinking on integrating web tech was evaluated.

This brought us to using an explanatory case study to investigate the experience of two instructors who went through the process to implement a lesson using web-based virtual reality. Characterizing design thinking through perceptions, processes, and outcomes, we were able to gain an understanding of what role did the process play. The results show that although there were different goals for implementation, the instructor was able to work within the IDDP framework to refine both the prototype and how they were approaching integration. Further analysis provided insight into the importance that translation of ideas to the developer and prototyping with the developer had within the IDDP. Looking at the limitations of this study brings generalization as an issue, which speaks on a need to have more investigation in the design partnership processes and how it can serve technological integration.

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APPENDIX A: IRB APPROVAL

ILLINOIS

OFFICE OF THE VICE CHANCELLOR
FOR RESEARCH & INNOVATION

Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Exempt Determination

March 8, 2021

Principal Investigator	Robb Lindgren
CC	David Tamayo
Protocol Title	*Using Web Based Authoring Tools to Overcome the Third Barrier to Classroom Technological Integration: Design Thinking*
Protocol Number	21705
Funding Source	Unfunded
Review Category	Exempt 2 (ii)
Determination Date	March 8, 2021
Closure Date	March 7, 2026

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Office for the Protection of Research Subjects (OPRS) has reviewed your application and determined the criteria for exemption have been met.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46.
- Requesting approval from the IRB prior to implementing major modifications.
- Notifying OPRS of any problems involving human subjects, including unanticipated events, participant complaints, or protocol deviations.
- Notifying OPRS of the completion of the study.

Changes to an **exempt** protocol are only required if substantive modifications are requested and/or the changes requested may affect the exempt status.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
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APPENDIX B: INTERVIEW GUIDE

Duration	Questions
5	**Research Protocol and orientation to interview**
	Design Perceptions
5	***Confidence in design practices*** **:** 1.Did you have experience designing teaching lessons with technology before Komodo? 2.How comfortable did you feel at first using Komodo to design classroom sessions?
5	***How are design problems interpreted:*** 1. Before using Komodo, did you already have an idea about how you wanted to design a lesson using technology? 2. How did you identify what features were needed for your lesson?
10	***What design processes are used:*** 1. What do you think helped you design your lesson in Komodo? 2. Were there any obstacles to meeting your lesson design ideas before using Komodo? 3. Were there any obstacles to meeting your lesson design ideas with Komodo?
	Design Process
5	***Empathy building:*** 1. What have your student experiences been with your designed lessons? 2. Do you feel that recognizing student experience has made you better at designing lessons for teaching?
5	***Collaboration:*** 1. How was your experience collaborating with developers/designers to reach your design goals? 2. What did you see as the most important in the collaboration?
10	***Iterative prototyping*** 1. How useful was it for you to test out the application before testing it out with students? 2. What was the most challenging part in designing a lesson to your liking using Komodo?
	Design Outcome
13	***Did it meet objectives sought:*** 1. Do you think the design choices accomplished what you intended? 2. What would you do different in terms of designing a future lesson for students? 3. What would you advice to a new teacher who wants to design a lesson through Komodo?
2	**Conclude research**
Total: 1h	